

Effectiveness of Scaffolding Technique in Scientific Learning Model on Students Mathematics Critical Thinking Skills and Self-Regulated Learning

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ABSTRACT

This study examines the effectiveness of a scientific learning model incorporating scaffolding techniques on students' critical thinking skills and self-regulated learning, as well as identifying contributing factors to its success. A mixed-methods approach with a quasi-experimental design was applied, involving 62 students randomly selected from two groups in a State Senior High School in Praya Regency. Critical thinking skills were assessed using essay tests based on defined indicators, while self-regulated learning data were collected through questionnaires. Observations of learning activities aligned with the lesson plan provided qualitative data. Quantitative data were analyzed using multivariate inferential analysis, while qualitative data were triangulated between observations and test results. The findings demonstrate that the scientific learning model with scaffolding techniques significantly enhances students' critical thinking skills and self-regulated learning compared to models without scaffolding. Scaffolding techniques, such as providing examples during observation, guiding questioning, modeling reasoning, and supporting communication through reporting findings, foster independent critical thinking habits. The results highlight the importance of scaffolding in guiding students through the stages of scientific learning. By systematically supporting their learning processes, students become better equipped to think critically and regulate their learning independently. The scientific learning model with scaffolding techniques is effective in improving critical thinking and self-regulated learning. Future research should explore its application across varied subjects and educational contexts to generalize its impact.

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1. INTRODUCTION

Critical thinking is one of the essential skills in the 21st century, along with collaboration, communication, and creative thinking. Critical thinking is defined as reflective and reasonable thinking

that determines what to believe or do (Ennis, 1996). It combines reliable mental processes, productive thinking, and evaluating evidence obtained to seek relevant and accurate knowledge (Jensen, 2008; Santrock, 2018). Critical thinking is related with mathematics as a knowledge that teaches how to think, logical proof, pattern arrangement, and concepts about interconnected numbers (Golding, 2018). Moreover, mathematics is often used as a science and strategy to understand and solve problems faced and shape students' mindsets (Burkhardt, 2006).

Critical thinking also plays an important role in mathematics learning by identifying, discovering, and understanding multifaceted mathematical concepts, as well as applying mathematical concepts appropriately when finding solutions to different problems (Paradesa, 2015). It can help students evaluate information correctly and improve decision making when faced with difficulties in solving problems. There are six levels of critical thinking skills: non-reflective thinking, challenging thinking, beginning thinking, thinking practice, advanced thinking, and mastering thinking (Elder & Paul, 2010). The critical thinking process involves six main skills: interpretation to understand clearly and identify information, sharp analysis, assessment and evaluation, inference, explanation, and self-regulated learning (Facione, 2011; Sanjaya, 2019). Self-regulated learning is important because it involves consciousness in the activities carried out from previous critical thinking processes.

Self-regulated learning is defined as a situation in which individuals involved in learning activities assume responsibility for controlling their own learning activities (Bandura, 1991). In self-regulation learning, learners consciously direct their behavior and mindsets systematically (Schunk & Zimmerman, 1994). Another notion of self-regulated learning is defined as a concept that explains how individuals manage their learning activities proactively to stimulate and motivate their cognition, affection, and psychomotor systematically and repeatedly to achieve success in the learning process (Zimmerman, 2002). Students have the ability to regulate their involvement in learning (Zimmerman, 1990). Thus, self-regulated learning involves a systematic process in two main aspects: understanding the lessons taught and forming a positive attitude towards learning.

Critical thinking skills and self-regulated learning can be obtained in learning activities that involve students actively exploring their knowledge. Clear instructions in the activity are needed to guide students, especially those experiencing difficulties (Van de Pol et al., 2010). However, in the learning activity, teachers often focus on presenting material only with examples but do not facilitate students to explore and elaborate; consequently, the students do not learn to think critically (Mason, 2007). Mathematics learning currently implemented in Indonesia has been recommended to be student-centered and use diverse relevant learning models (Mendikbudristek, 2022). One of the recommended learning models is scientific learning, which has syntaxes that allow students to explore.

Scientific learning can be explained as a learning approach based on a particular scientific theory (Akhmadi, 2015). The learning process with a scientific model involves three domains, namely affective, cognitive, and psychomotor, therefore, students can be productive, and think critically, innovatively, and creatively through strengthening integrated attitudes, skills, and knowledge (Shoimin, 2014). The scientific learning model organizes the learning process sequentially, starting from observing the phenomena or objects being studied carefully and systematically, formulating relevant questions and arousing curiosity to gain a deeper understanding, collecting various data, and conducting experiments to obtain the information needed, reasoning or associating by analyzing, connecting the information obtained with previous knowledge, and developing a more complex understanding through logical thinking, and communicating findings, conclusions, and understanding to others orally or in writing (Hosnan, 2014).

Scientific learning has been proven effective in mathematics learning in several aspects such as critical thinking, reasoning skills, problem-solving, collaborative, independent learning, and student interests (Lestari, Dwijanto, & Hendikawati, 2016; Wibowo, 2017; Wulandari, Dwijanto, & Sunarmi, 2015). However, not all students can follow scientific learning properly because of difficulties, especially when faced with new information or materials (Sutiarsa & Coesamin, 2018). One strategy that teachers can use to solve student learning difficulties is scaffolding (Adams & Hamm, 2010).

Scaffolding is a structured and specific form of guidance to assess students' understanding of their abilities and needs to become self-regulated learners (Fischer, Eden, & Pea, 2004). The guidance provided to students is temporary and designed to enable students to complete difficult tasks by forming their desired approaches and actions (Van de Pol et al., 2010). Woolfolk Hoy, (2021) describes scaffolding as a supporting framework in learning and problem solving including various forms of assistance, such as guidance, reminders, encouragement, dividing complex problems into manageable steps, providing examples, or using other strategies that encourage students' independence as learners. In addition, the use of trigger questions and modeling are also identified as forms of scaffolding (Mason, 2012). Scaffolding is important in the construction of knowledge and problem-solving during the mathematics learning process (Verenikina, 2003). Scaffolding involves expert support, in this case, teachers or peers who have mastered the concept (Slavin, 2017).

The main characteristics of scaffolding include contingency, which addresses student needs, fading, which involves gradually reducing assistance, and transfer of responsibility, which entails students learning independently to complete their tasks (Bakker, Smit, & Wegerif, 2015). Scaffolding typically begins by providing significant assistance to students during the learning process, and then gradually reducing the support so that students assume more responsibility once they understand the concept (Molenaar, Boxtel, & Slegers, 2011). Scaffolding has been proven to be effective in terms of cognitive and affective aspects such as learning outcomes, critical thinking skills, modeling skills, problem-solving, interest, enjoyment, self-efficacy, activeness, communication skills, activeness, and independence (Marshman & Brown, 2024; Roll, Holmes, Day, & Bonn, 2012; Schukajlow et al., 2012; Toh et al., 2014; Watson & Geest, 2012). Additionally, scaffolding techniques can be integrated with various learning models such as discovery learning, cooperative, inquiry-based, problem solving and scientific (Inayah, Hidayat, & Nur, 2020; Juniarso, 2020; Sofi, 2016; Toh et al., 2014).

Previous studies have shown that scientific learning models and scaffolding techniques are effective in many affective and cognitive domains. However, these studies did not concurrently analyze the effects on students' critical thinking skills and self-regulated learning. According to the literature review, the syntax of scientific learning and the character of scaffolding provision align with efforts to teach students critical thinking skills and self-regulated learning. Learning with scaffolding is expected to assist students in constructing the knowledge necessary for learning, allowing them to work independently.

This study aims to combine scientific learning models and scaffolding to teach critical thinking skills and self-regulated learning to grade X high school students while learning probability material. The probability material is a branch of mathematics with numerous real-world problems that are relate to students (Kepala BSKAP, 2022a). However, students in Indonesia often have difficulty understanding the concept of probability, differentiate between permutations and combinations, distinguish between independent and mutually exclusive events, and comprehend problems related to probability material (Astuti, Yusmin, & Suratman, 2015; Fitri & Abadi, 2021; Putridayani & Chotimah, 2020; Sinaga, Siagian, & Hasibuan, 2021). Therefore, this study will investigate whether the implementation of scientific learning combined with scaffolding techniques is effective for enhancing critical thinking skills and self-regulated learning in grade X high school students. In addition, it will explore the learning activities that contribute to the effectiveness of scaffolding techniques in the scientific learning model on students' critical thinking skills and self-regulated learning.

2. METHODS

This study employs a mixed-method research approach, integrating both quantitative and qualitative methods to provide a comprehensive analysis. The quantitative component uses a quasi-experimental post-test-only control group design to evaluate the effectiveness of scaffolding techniques in scientific learning on critical thinking skills and self-regulated learning. The qualitative component adopts a phenomenological approach to explore how scaffolding techniques facilitate critical thinking

and self-regulated learning. This research design was selected due to the random assignment of students into experimental and control groups (Creswell, 2014).

The study population consisted of all class X students at a State Senior High School in Praya City during the 2022/2023 academic year, totaling 408 students across 13 classes. Simple random sampling was used to select two classes: class X11 (32 students) as the experimental group and class X12 (30 students) as the control group. The experimental group was taught using a scientific learning model enhanced with scaffolding techniques, while the control group followed the same scientific learning model without scaffolding.

In the experimental group, scaffolding techniques were systematically integrated into the scientific learning process. This included trigger questions during observation, illustrative examples during questioning, modeling during practice, and structured guidance for communicating findings. The intervention was conducted over four sessions, each lasting 2 x 45 minutes, and focused on the probability concepts of mutually exclusive events, and mutually independent events, determining probabilities for these concepts, and solving related problems.

Data collection for student's critical thinking skills utilized essay tests developed by the authors consisting of four questions on probability material. The indicators included determining the probability of mutually exclusive events from an experiment, determining the probability of mutually independent events in a random experiment, determining the probability of permutations and combinations in an experiment, and solving problems related to event probabilities. The indicators of critical thinking skills were based on Facione (2011) and included interpreting information to answer questions (interpretation), finding the correct concept in solving questions (analysis), determining accurate calculation (evaluation), and drawing conclusions (inference). Each correct response was scored as 1, while incorrect response was scored as 0. Data on students' self-regulated learning were collected through a questionnaire with 25 items using a Likert scale of 4 answer choices, namely always (4), often (3), rarely (2), and never (1). Indicators of students' self-regulated learning included understanding learning needs, setting learning goals, exercising self-control, taking learning initiatives, implementing learning strategies, and evaluating the learning process and results. Factors affecting the effectiveness of scaffolding techniques in scientific learning on students' critical thinking skills and self-regulated learning were assessed using observation sheets based on the lesson plan.

Quantitative data analysis included descriptive and inferential analysis techniques. Descriptive analysis involved average, standard deviation, maximum, and minimum scores. The effectiveness of the treatment in the experimental and control group regarding critical thinking skills and students' learning independence, as well as the simultaneous difference in effectiveness between the experimental and control groups in terms of critical thinking skills and students' self-regulated learning, the data analysis technique used was the *Manova*-test. The effectiveness criteria for the critical thinking ability variable are that the average reaches 75 on a scale of 0-100, while the effectiveness criteria for the learning independence variable is that the average reaches 72 on a scale of 25-100. Decision-making for effectiveness criteria uses the initial limit of the high category following the categorization (Azwar, 2016). Meanwhile, qualitative data analysis involved triangulating data from observation sheets and student work results.

3. FINDINGS AND DISCUSSION

The results of quantitative data analysis include descriptive analysis and inferential analysis. The results of descriptive analysis related to students' critical thinking skills and self-regulated learning from the experimental and control groups can be seen in Table 1.

Table 1. Description of students' critical thinking skills and self-regulated learning.

Description	Experiment group		Control group	
	Critical thinking	Self-regulated learning	Critical thinking	Self-regulated learning
Mean	85.43	88.30	82.03	84.46
Standard deviation	6.50	4.19	7.69	4.69
Maximum	100	100	100	100
Minimum	0	25	0	25

The average critical thinking scores of the students in the experiment and control groups (Table 1) are both at a high level, based on score categories from Azwar (Azwar, 2016). The average critical thinking scores of both groups exceed the effectiveness criteria (75). The average critical thinking score of the experiment group ($M=85.43$) is higher than that of the control group ($M=82.03$), although the variance is smaller. This suggests that the critical thinking abilities of the experiment group students are better and more evenly distributed compared to the control group. Most students can understand problems, identify information, draw conclusions, and choose strategies for solving problems, despite some errors in the calculation process. The difference lies in the calculation process, where the experiment group students outperform the control group students.

The average self-regulated learning scores of the experiment group are in the very high criteria ($M > 85$) while the control group scores are in the high criteria ($72 < M \leq 85$) (Azwar, 2016). Both groups' self-regulated learning scores surpass the effectiveness criteria (72). The average self-regulated learning score of the experiment group ($M=88.30$) is higher than that of the control group ($M=84.46$), with a slightly smaller variance. This indicates that the students' self-regulated learning levels in the experiment group are superior and more evenly distributed than those of the control group. Most students understand the purpose of learning mathematics, the necessity of learning it, and can choose appropriate learning strategies. However, students struggle with self-control and evaluating their learning outcomes.

Students with high critical thinking skills tend to achieve better mathematics learning outcomes because they can easily understand and differentiate between concepts (Chukwuyenum, 2013). This aligns with research showing that critical thinking skills positively impact students' math achievement by enabling them to synthesize, analyze, and draw conclusions during learning activities (Fatmawati, Zubaidah, & Mahanal, 2019). Critical thinking skills are associated with high-level thinking that involves analysis and reasoning, leading to higher-order thinking skills (Widana, Parwata, & Sukendra, 2018). Students with strong critical thinking skills can grasp concepts from various perspectives, enhancing their interest and performance in solving real-life math problems (Aksu & Koruklu, 2015).

Descriptive statistics also show a correlation between high critical thinking skills and high self-regulated learning in students. Facione (2011) suggests that self-regulation is essential for critical thinking, involving understanding, differentiation, analysis, and evaluation. Self-regulated learning plays a crucial role in students' academic success and future achievements (Azmi, 2016). Students' ability to regulate their learning helps them find relevant sources and solve complex problems, aligning with the national educational goal of producing independent, critical thinkers (Kepala BSKAP, 2022b; Sun et al., 2018). Self-regulated learning contributes to shaping students into lifelong learners, in line with national education objectives (Undang-Undang Nomor 20, 2003).

A multivariate test was conducted to assess the effectiveness of the scientific learning model with scaffolding techniques on critical thinking skills and students' self-regulated learning, as well as the differences in effectiveness between the experimental group and the control group. The data met the assumptions for normality and homogeneity, allowing for the use of a multivariate test to assess differences between the groups. The results of the multivariate test for the effectiveness of the experimental group, $F(2, 30) = 32.867$, $p = 0.00$, showed a statistically significant difference. Therefore, the scientific learning model with scaffolding techniques was effective in terms of critical thinking skills

($M = 85.4 > 75.0$, $SD = 6.5$) and self-regulated learning ($M = 88.3 > 72.0$, $SD = 4.2$). Meanwhile, for the control group, the value of $F(2, 28) = 15.764$, $p = 0.00$ showed a statistically significant difference. This indicated that the scientific learning model without scaffolding techniques was effective in terms of critical thinking skills ($M = 82.0 > 75.0$, $SD = 7.7$) and self-regulated learning ($M = 84.5 > 72.0$, $SD = 4.7$).

As the implementation of scientific learning combined with scaffolding techniques and without scaffolding techniques are effective in critical thinking and self-regulated learning, the effectiveness differences between the experimental group and the control group will be analyzed. The multivariate test of the difference in effectiveness between the experimental group and the control group, the value of $F(2, 60) = 6.102$, $p = 0.00$ was obtained, indicating that there was a difference between the two groups in terms of critical thinking skills and self-regulated learning. The critical thinking skills ($M = 85.4$, $SD = 6.5$) and self-regulated learning ($M = 88.3$, $SD = 4.2$) of the experimental group are higher than the critical thinking skills ($M = 82.0$, $SD = 7.7$) and self-regulated learning ($M = 84.5$, $SD = 4.7$) of the control group. This means that the scientific learning model combined with scaffolding techniques is more effective than the scientific learning model without scaffolding techniques in terms of students' critical thinking skills and self-regulated learning simultaneously. Additionally, the scientific learning model with scaffolding techniques has medium practical significance on critical thinking ($\eta^2 = 0.06$) and very high practical significance on self-regulated learning ($\eta^2 = 0.16$) following Cohen's eta squared effect size category (Cohen, Manion, & Morrison, 2018).

The results of the multivariate analysis showed that the scientific learning model, both with and without scaffolding techniques, proved effective in terms of students' critical thinking skills and self-regulated learning. The results of this study are in line with the research conducted by Zohar and Barzilai (2013), which generalized that learning with a scientific approach can improve students' critical thinking skills. Students who are involved in scientific experiments and discussions tend to show improvements in their ability to analyze, evaluate, and solve problems. The results of other studies support this by showing that the scientific approach can promote students' self-regulated learning (McNeill & Krajcik, 2008). Students who are involved in scientific-based learning activities have better abilities in controlling their learning processes, including goal setting, effective strategy use, and reflection on progress. Meanwhile, the effectiveness of the scaffolding technique is in accordance with the statement of Pritchard and Woollard (2010), which states that scaffolding effectively encourages the acquisition of knowledge and development of conceptual understanding in students which is part of critical thinking skills.

According to the results of the effectiveness difference test, the scientific learning model combined with scaffolding techniques is more effective than the scientific learning model without scaffolding techniques in terms of students' critical thinking skills and self-regulated learning. This study is in line with the results of other studies which concluded that providing scaffolding makes learning more effective in achieving its goals such as conceptual understanding, critical thinking, and computational thinking skills compared to not using scaffolding (Jatisunda & Nahdi, 2020; Marchelin, Hamidah, & Resti, 2022). The integration of scaffolding in learning activities is also more effective in teaching self-regulated learning to students (Nurhayati, 2017). The results of this study differ from research by Schukajlow et al. (2012), which found no difference in student learning outcomes between those given scaffolding and those not given scaffolding. Schukajlow et al. (2012) already included instructions on how to carry out modeling in their activities, on the other hand, the activities in this study were given in accordance with scientific learning syntax, hence students purely carried out experiments independently.

Scaffolding techniques serve as a bridge in scientific learning, making the learning process more effective and aligning with the observed results of the learning activity. When encountering challenging concepts, teachers can inspire students by offering simpler, related problems with easier calculations before gradually reducing assistance over subsequent meetings. For instance, the teacher presented a fishing problem to students, asking, "If there are 5 fish in a pond, 2 tilapia and 3 gourami, what is the probability of catching a tilapia fish on the first try?" As students progress, they begin to make independent observations and enhance their critical thinking skills.

During the questioning stage, teachers guide students on what to ask when they encounter difficulties and encourage them to develop questions based on the problems at hand. These questions can then be used as discussion points to promote critical thinking among students. In the trying and analyzing stage, teachers demonstrate how to translate a problem into a mathematical equation, prompting students to experiment with different approaches and analyze the outcomes. For example, students may explore variations of the fishing problem to understand the relationship between different results.

In the final stage of communication, students are encouraged to articulate their findings, the connections between their experiments, and how they arrived at a particular concept. They share their insights with classmates, fostering collaborative discussions. As students become more adept at problem-solving, scaffolding assistance is gradually reduced, with teachers offering guidance only when students struggle to comprehend or select a strategy for problem-solving. By providing structured support throughout the learning process, teachers help students develop critical thinking skills and a sense of responsibility for independent learning.

According to the qualitative results, the scaffolding provided by the teachers gradually decreased from the first session to the last session. For example, in the first session, the teacher guided the student by giving a clue on how to analyze a problem using 5W1H, how to connect it with probability theory, and how to elaborate on the problems to deepen the student's understanding. In the second session, the teacher reduced the clues to only reminding the student how to analyze different problems using the same method as the previous session and giving a clue when the student faced difficulty. During the last session, the teacher observed how the student could think critically and independently to solve the different problems given. The fading process required the student to prepare for the next session in order to solve the problems independently. This result strengthens the findings of Shih, Chen, Chang, and Kao (2010) that gradually reducing teacher involvement in student activities can help students develop self-regulated learning, such as obtaining supplemental materials, understanding learning goals and patterns, as well as sustaining interest in learning.

The provision of scaffolding at different levels in each session has been shown to enable students to model how to solve problems by conducting experiments and presenting the results of the solution. This aligns with what Santrock (2018) conveyed, that scaffolding involves adjusting the level of support provided during a teaching session, either by a teacher or peers, according to the student's abilities. Scaffolding is provided for a certain period according to the students' needs (Akani, 2015; van de Pol, Volman, Oort, & Beishuizen, 2015). Varying the provision of scaffolding by providing trigger questions, modeling examples, and writing reports also aligns with the opinion of Hamm and Adams (2013) that scaffolding can vary depending on the learning process being carried out, whether it be understanding or application. Scaffolding can act as a bridge in someone's development process to help them achieve their goals, as experts (teachers) assist novices (students) in accordance with the zone of proximal development theory/ZPD (Xi & Lantolf, 2021). The interaction and conversation between students and teachers during learning allows them to enhance their ZPD for critical thinking, as students can learn how to think critically when faced with a problem (Wass, Harland, & Mercer, 2011).

In mathematics learning, scaffolding is suitable as an effort to guide students who are experimenting to understand how concepts and principles make learning meaningful (Kennedy, Tipps, & Johnson, 2011). Meaningful experiences from teachers' guidance during learning can open students' insights in viewing problems or learning contexts from different perspectives. Gradually reducing the provision of scaffolding in each session is expected to make students independent learners in the classroom (Saks et al., 2015). Students are expected to become accustomed to organizing themselves to try to understand problems, identify important information, analyze solution steps, evaluate work results, and report work results. An example of how a student can independently solve problems critically in her own way can be seen in Figure 1.

Soal	Jawaban
<p>3. Deni dan Dina melakukan percobaan pelemparan dua buah dadu dengan enam sisi beberapa kali sebagai tugas rumah dari gurunya. Dari hasil percobaan, mereka menyatakan bahwa:</p> <p>a. Peluang munculnya dua mata dadu dengan jumlah 5 adalah $\frac{1}{3}$</p> <p>b. Peluang munculnya dua mata dadu dengan jumlah ganjil adalah $\frac{1}{2}$</p> <p>Tentukan mana yang benar atau salah dari pernyataan mereka disertai penjelasan jawabannya!</p>	<p>3) Peluang munculnya dua mata dadu dengan jumlah 5 adalah $\frac{1}{6}$.</p> <p>Untuk mendapatkan jumlah 5 dari dua dadu kombinasi yang mungkin adalah:</p> <ul style="list-style-type: none"> • (1,4) • (2,3) • (3,2) • (4,1) <p>Jadi, ada 4 kombinasi yang menghasilkan jumlah 5. Total kemungkinan hasil pelemparan dua dadu adalah $6 \times 6 = 36$.</p> <p>Maka, peluangnya adalah:</p> $P(\text{jumlah 5}) = \frac{4}{36} = \frac{1}{9}$ <p>Pernyataan a) salah!</p> <p>Peluang munculnya dua mata dadu dengan jumlah ganjil adalah $\frac{1}{2}$.</p> <p>Jumlah ganjil dapat terjadi jika:</p> <ul style="list-style-type: none"> • dadu pertama ganjil dan dadu kedua ganjil • dadu pertama ganjil dan dadu kedua genap <p>Kombinasi yang menghasilkan jumlah ganjil adalah:</p> <ul style="list-style-type: none"> • (1,2), (1,4), (1,6), (2,1), (2,3), (2,5), (3,1), (3,3), (3,5), (4,1), (4,3), (4,5), (5,1), (5,3), (5,5), (6,1), (6,3), (6,5) <p>Terdapat 18 kombinasi yang menghasilkan jumlah ganjil.</p> <p>Maka, peluangnya adalah:</p> $P(\text{jumlah ganjil}) = \frac{18}{36} = \frac{1}{2}$ <p>Pernyataan b) benar!</p>

Figure 1. Example of student's posttest worksheet

Figure 1 shows that the student can understand each problem very well, identify and analyze the solution correctly using her own method. At point B, the student explained that if 2 dice are thrown and the result is odd, the possibility is that the first dice is odd and the second dice is even, or the first dice is even and the second dice is odd. She then listed the sample points and calculated the probability. The way the student answered the question followed the teacher's guidance during the learning activity to think step by step and combine it with her own approach. The student could have used a shorter answer for the sample points by calculating the probability of the first possibility and the second possibility, which could be written as $(3 \times 3) + (3 \times 3)$, instead of listing all the sample points to ensure the process and results are correct even without any instruction in the task. This proves that the student has independently thought critically in solving problems.

The provision of scaffolding in this study follows the instructions in the national education process standards, which state that a teacher must be able to facilitate and guide students to be actively involved and enjoy learning (Mendikbudristek, 2022). The teacher gives the students the freedom to think about solving problems, but carefully guides them if they encounter misunderstandings or difficulties. The main goal of the learning activities carried out is to achieve the planned learning objectives, including competency in the material and additional competencies such as critical thinking skills and self-regulated learning of students.

The effectiveness of learning with scientific models combined with scaffolding can be applied to other materials, especially materials that allow experiments to be carried out to find concepts. In addition, learning can also be combined with the use of application assistance or learning media such as GeoGebra for learning geometry and linear equation systems. To implement this, it is necessary to pay close attention to the integration between the syntax of the scientific learning model and the type of scaffolding provided to make students actively explore and learn to interpret the process being carried out.

Scaffolding can also be integrated into different learning models. The teacher can provide scaffolding using contextual examples of the concept or step-by-step examples to understand the problems given. Simple questions like "What do you think?" "What if?" or "How do you find?" may be used to ignite students' critical thinking ability to understand the problems and elaborate on the examples. Teachers also need to analyze when they should give students scaffolding and when they have to fade it to make students learn independently and critically. Scaffolding can be implemented in the Project of *Penguatan Profil Pelajar Pancasila* (P5) to guide the students in creating and developing ideas from their raw idea.

The complexity of the scaffolding context's relation to many aspects is nearly impossible for the author to measure. The experiment was also conducted for a short period, which made it unable to observe students' critical thinking and self-regulated learning progress gradually. The effect of scaffolding on students did not differentiate between high-ability or low-ability students, which may have different

effects. The critical thinking assessment used only essay tests, which could be expanded to different forms like multiple choice answers and integrated into the national assessment framework using non-routine problems (Kemendikbud, 2022). Moreover, this study did not collect the students' perceptions regarding scaffolding implementation to enhance their critical thinking and self-regulated learning.

4. CONCLUSION

Based on the results of the analysis, the scaffolding technique in the scientific learning model is significantly effective in terms of students' critical thinking skills and self-regulated learning. Additionally, when the scientific learning model is combined with the scaffolding technique, it is significantly more effective than scientific learning alone in terms of students' critical thinking skills and self-regulated learning simultaneously. The scaffolding technique is effective because it complements scientific learning by assisting with questioning in observation activities, providing relevant and simpler examples during questioning activities, offering modeling examples during practice and reasoning activities, and highlighting important aspects when solving problems that need to be communicated during communicating activities.

The scaffolding technique is crucial in helping students transition from understanding real-world context to abstract concepts in mathematics learning, aligning with the goals of Indonesia National Curriculum. However, this study has limitations as it did not analyze the differences in students' levels of critical thinking skills and self-regulated learning of students. This study also does not explore students' perceptions at different levels of critical thinking skills and self-regulated learning regarding the implementation of the learning process to ensure it meets their needs. Therefore, future research could investigate how students' level of self-regulated learning and their perceptions impact critical thinking skills when using scaffolding techniques with other mathematics materials.

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